Integrated Assessment Model for Urban Energy Network System

EnviroInfo2008
Environmental Informatics and Industrial Ecology
September 10-12, 2008,
Leuphana University of Lüneburg, Germany

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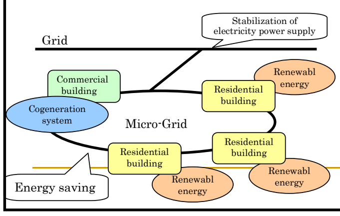
1.Intoroduction

Intoroduction-1

Renewable energy resources are unstable and affect electricity grids when fully linked.

Distributed energy supply network system



A network system that transfers electricity and heat between dispersion generators and renewable energy resources to supply stable energy to an urban district is required.

Intoroduction-2

1.Early studies

Studies that aim at balancing energy saving and maintaining the electricity quality via the networking of distributed energy have been conducted in various organizations.

- "Micro-grid"
- "SMART"
- "Neighborhood association cogeneration"
- "FRIENDS," and "Demand place network"

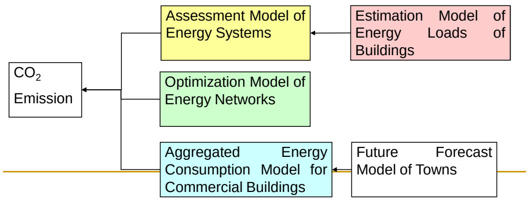
2.Improvements of our study

- Constructed a model to evaluate a distributed energy supply network system in an urban district.
- This model aims at optimizing the possibility of energy saving and energy exchange between commercial and residential buildings in a district.
- Applied the model to an urban district, Utsunomiya, which is a typical mid-size city in Japan.

Intoroduction-3

The model is a combination of several models:

- District Model
- Eestimation model of energy demands of buildings,
- Optimization model of energy networks,
- Aassessment model of energy systems (evaluation model of air conditioning systems), and
- aggregated energy consumption model of commercial buildings.



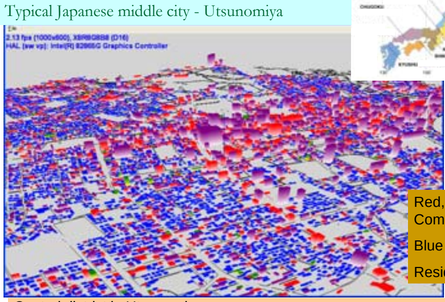
2.Estimation Model

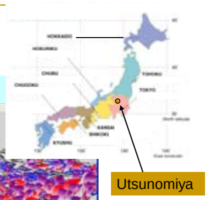
2.1 District Model

2.Estimation Model

2.1 District Model

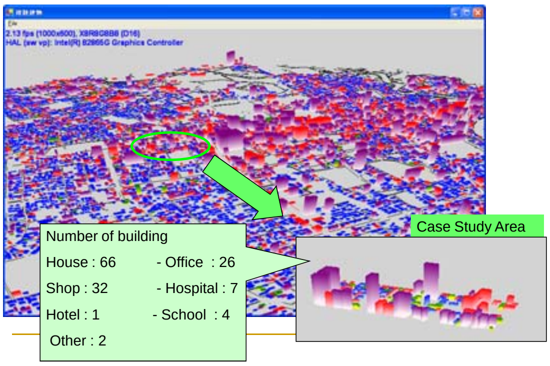
Typical Japanese middle city - Utsunomiya



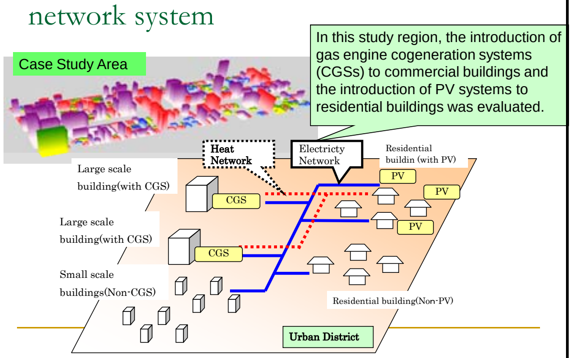


Central district in Utsunomiya
- Intermingglement of residential buildings and commerce buildings.

Selected Area ; case study



Outline of the distributed energy supply network system



2.Estimation Model

2.2 Estimation model of Energy Loads of Buildings

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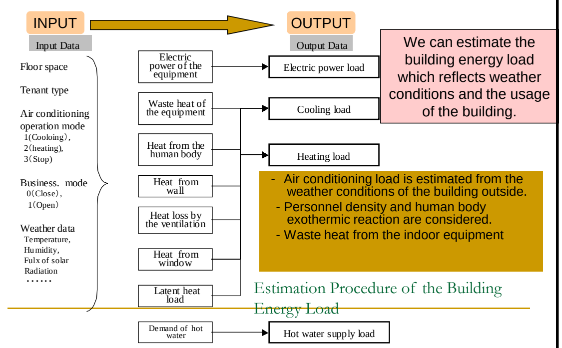
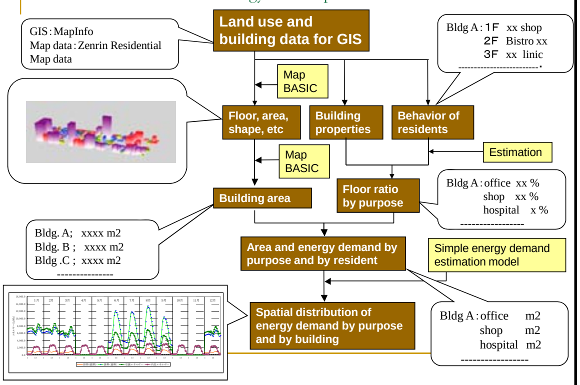


Estimation Procedure of the Building Energy Load

Estimation Procedure of Energy Consumption



Comparison of the Estimated Value and the Measured Data of the Annual energy Consumption

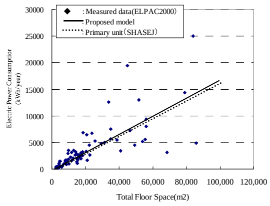


Fig. Comparison of the annual electricity consumption (office)

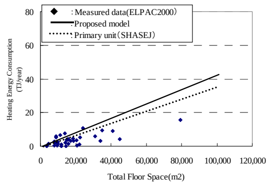
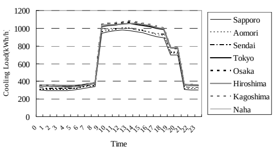


Fig. Comparison of the annual heat consumption (office)

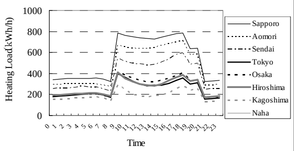
Our model estimates appear within the actual energy load statistics.

Building Energy Load Patterns of the Cities

Cooling load (August)



Heating load (February)



Estimate assumptions

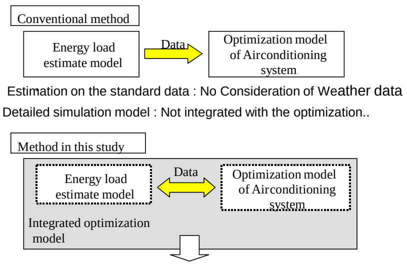
- Floor Space : 10,000m²
- Uses of building : office 20%, shop 20%, hotel 60%

The energy loads vary depending on the regional climate conditions.

2.Estimation Model

2.3 Energy network optimization Model

Outline of the Optimization Model in Our Study

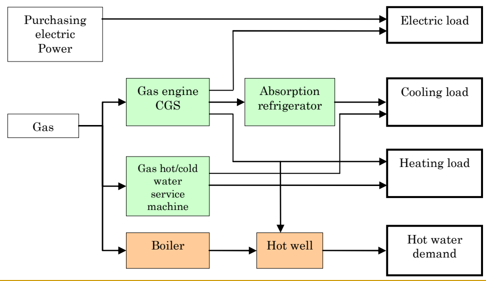


Consideration of Weather data

Consideration of partial load properties of energy systems by mixed integer nonlinear programming.

Integration of the estimate model of a building energy load and optimization model of the energy system.

Modeling of the Air Conditioning System



Alternatives of air conditioning system

-Heat pump system

-Cogeneration system

-Gas hot/cold water service machine and boiler

Model Equations of Optimization

Composition of equations

- Energy demands on the electricity and heat
- Energy balances of the equipments
- Model of partial load properties of Heat pump system / Cogeneration
- Conditions on operation of cogeneration system

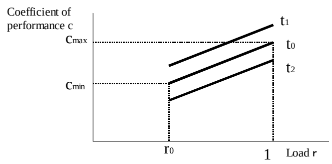
Constraint on the economic efficiency

- Investment return year ＜ X year

Objective function ： Minimization of Primary Energy Demand

Modeling of the Partial Load Properties of the Heat Pump System

- Efficiency is approximated by a liner function of the load factor.
- Lower limit of the partial load is formulated with a binary variable.

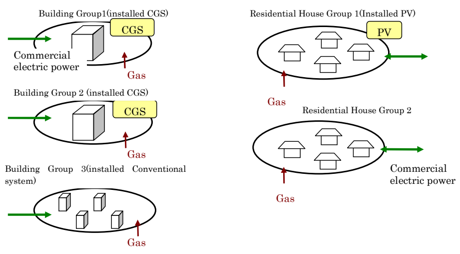


$\delta = \{0,1\}$; $r \le \delta$ and $r \ge r_0 \cdot \delta$

$$c = \left\{ c_{\min} + (r - r_0) \times \frac{c_{\max} - c_{\min}}{1 - r_0} \right\} \times (t - t_0)\Delta c$$

Conditions of Case Study

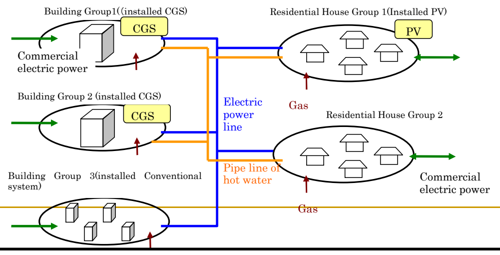
Case 1 : installation of a standalone CGS and PV



Conditions of Case Study

Case 2 : installation of CGS and energy transportation network

Case3: installation of CGS and energy transportation network under the minimization of electricity sale from the district.

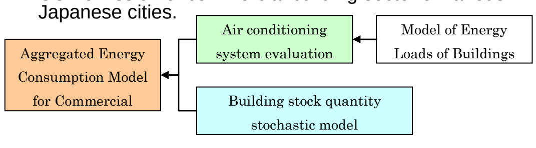


2.Estimation Model

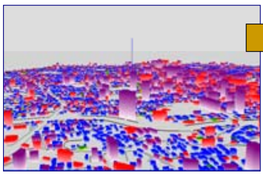
2.4 Aggregated Energy Consumption Model for Commercial Buildings

Aggregated Energy Consumption Model for Commercial Buildings

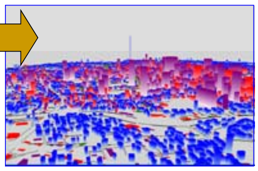
- With regard to the CO_2 emission reduction from commercial buildings, a method was developed for evaluating the multiple effects of CO_2 reduction countermeasures.
- The model combines building energy load model, air conditioning system evaluation model and building stock quantity stochastic model. This model can calculate the CO_2 emission of commercial building sector of various Japanese cities.



- We constructed a future expansion model for towns. It is assumed that a buildings are updated at random, and then a projjected figure of the city is drawn.



Present 3-D view of the case study region



Future 3-D view of the case study region

3.Result

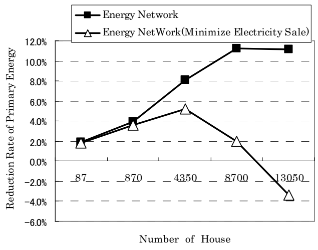
Primary Energy and CO2 Emission from the Case Study Region

Case		Optimum capacity of co-generation system (kW)			Primary energy of the area (Gcal/year)	CO2 emission of the area (t -CO_2/year)	Electricity Sale (MWh)
			Building Group 1	Building Group 2			
Case 1	Non Network	First Unit	249	327	108,113	18,797 [28,104]	5,464
		Second Unit	896	474			
		Sum	1,145	801			
Case 2	Energy Network	First Unit	534	0	106,052	18,674 [26,846]	4,898
		Second Unit	1,409	843			
		Sum	1,944	843	(-1.9)		
Case 3	Energy Network Minimize Electricity S	First Unit	523	0	106,124	18,669 [26,917]	0
		Second Unit	1,350	689			
		Sum	1,872	689	(-1.8)		

※Numerical value in the parenthesis[ ] used emission factor of the average of thermal power plant.

There exists a solution that can help achieve energy saving while minimizing the sale of electricity to the district.

Reduction Rate of Primary Energy



The energy saving rate was the maximum when the number of residential buildings was under approximately 4000.

Reduction Rate of Primary Energy in the City

- With regard to the network of CGS building and PV houses, the optimization conditions for maximizing the energy saving rate (primary energy reduction rate) are shown below.

-The maximum number of residential buildings within a floor space of 10,000 m2 = 133

- Energy saving rate = 11.0%

-Condition : There are buildings over 10,000m2 in total in a district, and there are houses more than 133 houses per 10,000m2 floor space in a district.

The energy saving for the entire Utsunomiya-shi was 4.4%.

Summary and Future Directions

-We constructed a model to evaluate the optimum installation and operating conditions of equipments that depend on the regional climatic conditions and to evaluate the technological characteristics of the energy systems using nonlinear mixing integer programming.

-It can be concluded that the model developed in our research is superior in performance as compared to the existing tools and thus contributes to the optimum decision planning of a regional energy supply network using the recent complex and increasing technological options.

- Next plan

(1) elucidation of a combination of new energy resources that is necessary for the stabilization of electricity power supply,
(2) developing energy saving methods, and
(3) attaining an optimum balance between demand-side constitution.